AOI vs. AFI

IN PCB DEFECT DETECTION

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This article addresses the major differences between Automatic Optical Inspection (AOI) and Automatic Final Inspection (AFI). AOI is currently used in several stages of the PCB inspection, while AFI is an additional technology used at the end of the PCB manufacturing process.

AFI requires a different technology than AOI resulting in new conceptual machines. The traditional AOI is based heavily on verification, and will probably remain so for some time. The urgent need for AFI has lead to sophisticated learning machines that do not incorporate human verification as part of the system.

Analysis

The idea behind AOI for printed circuit defects is based mainly on finding the missing or extra elements of a board. The PCB manufacturing process is based on chemical and mechanical actions that may damage the intended design. Frequently, various PCB defects such as cuts, opens, nicks, protrusions, mouse bites, pin holes, missing or extra copper, incomplete drills, and narrow or wider conductors occur during production. These kinds of defects should be found by automatic visual inspection.

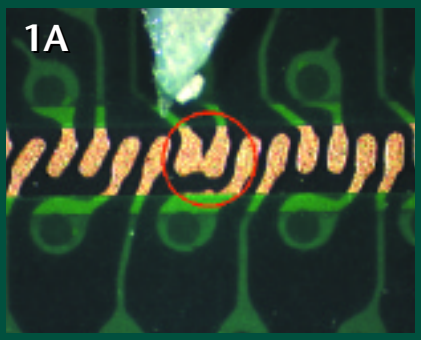
AOI machines were built and designed for the task of finding such defects on large PCB panels, while maintaining a certain production rate. The common algorithmic methods of finding these PCB defects are based on a comparison between the inspected image and the reference image. Methods such as local feature matching, image skeletonization and morphological image comparison are widely used by most AOI manufactures. Design rule check measurement algorithms are an exception since they do not need a reference image to detect defects.

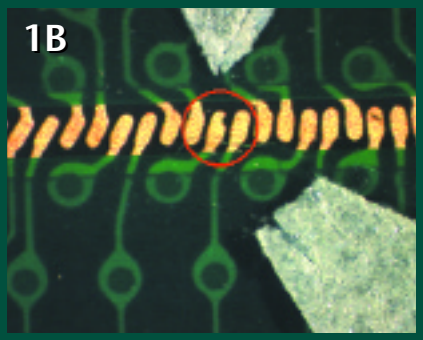
The AOI algorithms usually find most, if not all, of the defects. However, production problems, including oxidation, dust, contamination, and poor reflective materials, lead to almost inevitable false alarms and the need for human verification. For this reason, all AOI rooms are equipped with many verification stations which require human operation. PCB manufacturers accept the idea that with any AOI machine there are several verification machines, and even see them as a necessity. (Instead of performing verification on a separate machine, it is possible to inspect and verify the panels on a single AOI system.)

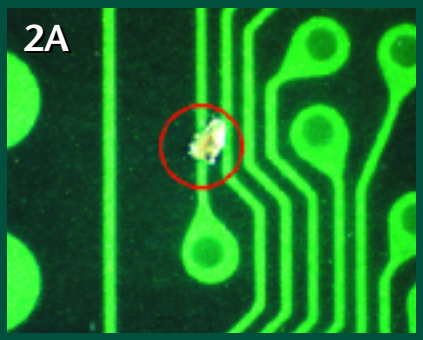
Until verification is automated, incorporating automatic handling in AOI systems may prove to be fruitless because human verification is required and every panel must be handled manually during the verification stage.

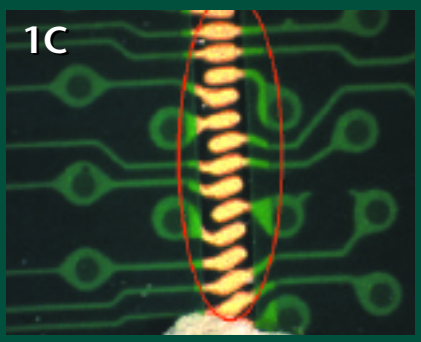
AFI is a growing need in BGA and gold plated applications. Unlike AOI, AFI looks for surface defects such as gold contamination, discoloration, scratches, and bare copper parts. It also looks for defects under the solder mask such as air bubbles and dust. AFI is performed on smaller PCB parts and larger quantities than the PCB panels inspected by AOI. It avoids any extra manual handling by precise defect detection: for these reasons the concept of full automatic handling is essential. AFI must utilize sophisticated learning machines which give highly accurate predictions. Furthermore, its algorithms must be based on statistical texture analysis methods, combined with machine learning techniques, making the learning phase essential.

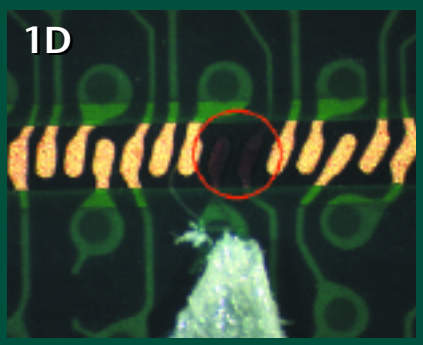
The concept of Auto Verification (which is based on a smart post processing segmentation and classification method) is also an essential ingredient which makes the decision and defect identification more precise. AFI must be based on sophisticated pre-processing and post-processing stages. Preprocessing involves the intervention of human knowledge, by applying a teaching and rule-based mechanism, while the post processing phase uses the acquired knowledge for smart classification and decision-making.

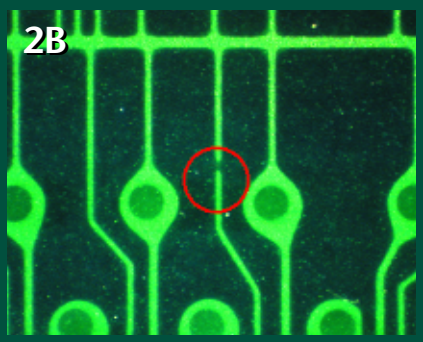












It is an easy and natural process to train a common operator to detect the described defects, and to provide rules for analysis in order to separate between acceptable vs. non-acceptable critical defects. We use both verbal description and visual examples for training in order to generalize the rule. This is not trivial in standard Computer Vision approach. The rules may be well defined for a few examples, but there is a long way to go until we can provide the system with general parametric criteria for distinguishing between valid and invalid defects. The criteria for defect acceptance varies from one customer to another.

When it comes to AFI, the customer criteria and defect definitions differ from one type of area to another, e.g., wire bonding gold pads, BGA pads and power lines and solder mask laminated areas.

Shape Violation Defects vs. Surface Defects

Example 1. ***Examples of a Short, a Mouse Bite, Under Etching, and Bare copper.***

The defects above are similar to typical AOI applications, where the Vision System is required to detect irregularities in the shape of a 'known' object which is easily separated from its background (e.g., missing or extra objects are compared to a well defined reference).

Example 2. ***Foreign materials on SM (left) and open under SM.***

Example 3. ***Scratches.***

A scratch may be of different shapes (straight, curved, long/short), orientations and depths according to the mechanical force that was applied as a result of poor handling.

Example 4. ***Nodules.***

Defects such as nodules are much more complex to define (irregularity in surface quality). We can describe this verbally as "the area of difference" on the viewed surface.

Example 5. ***Solder Mask Contamination.***

Summary

We've demonstrated the complexity of surface defects detection and classification in AFI. This complexity creates the need for advanced approaches that can handle different customer requirements in a reliable manner. The next generation of AFI systems must combine both high detectability along with superb analysis capabilities in order to provide a very low false alarm solution.

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